A Critical Analysis of IMO S-Mode Guidelines

P. Zalewski
Maritime University of Szczecin, Szczecin, Poland

ABSTRACT: Circular on "Guidelines for the Standardization of User Interface Design for Navigation Equipment", commonly known as "S-Mode Guidelines", has lately been approved by International Maritime Organisation. Its potential impact on default and common user settings of radar equipment, electronic chart display & information system, and integrated navigation system has been discussed in the article. Several issues that should be considered during technical implementation of the circular provisions and follow-up familiarization of navigators with the affected equipment have been identified.

1 INTRODUCTION

During 6th session of International Maritime Organization (IMO) Navigation, Communication, Search & Rescue Sub-Committee (NCSR) the "Draft Guidelines for the Standardization of User Interface Design for Navigation Equipment", commonly known as S-Mode guidelines [IMO, 2019], were approved, and transferred further to IMO Maritime Safety Committee (MSC) for final adoption. Nowadays and in the past significant variation between navigation systems and equipment produced by different manufacturers has led to inconsistency in the way essential information is presented, understood and used to perform key navigation safety functions [Bhuiyan, 2012; NI, 2017]. Recognising this fact the objective set for the novel S-Mode guidelines is to promote standardization of user interfaces to help meet user needs, and specifically to locate and understand important information quickly and enhance all levels of situation awareness, such as perception, comprehension and projection of situation that will assist in the seafarer's decision-making process. While

this objective is undisputable, the question if the guidance within these guidelines leads to navigation safety improvement remains valid because several potential issues concerning its interpretation can be identified.

In the following sections the possible negative implications of careless guidelines' implementation in newly designed interfaces of radars, electronic chart display systems (ECDIS), integrated navigation systems (INS) and other navigation related equipment have been discussed.

2 GUIDANCE WITHIN THE GUIDELINES

The key reason behind the S-Mode guidelines development has been expectation that improved standardization of the user interface and information used by seafarers to monitor, manage and perform navigational tasks should enhance situation awareness and improve safety of navigation. It is stressed in the guidelines that although the operation

of navigation equipment requires specialist training and familiarization, variations across different manufacturers' equipment for mandatory functions should be minimal. Where there is significant variation in buttons, icons, actions, workflows, processes, units of measure or location of information, there is a commensurate increase in the time required for equipment familiarization and the risk of operational error, particularly in challenging navigational situations. Users need to accumulate knowledge, skills and experience of using essential functions, which can be transferred between the systems and equipment of different manufacturers. To reduce familiarization time and risk of erroneous action, essential functions and information need to be located in consistent locations, be of a similar size, recognizable by location, colour and shape. Units of measurement should also be consistent. That is why the standardization design principles and findings stemming from research into human factors, cognitive science, and human-centred design (HCD) [Mosier, 2010] have been applied to the technical content of the S-Mode guidelines comprising:

1 default and user settings;
2 terminology, abbreviations and icons for commonly-used functions (hot keys) and groups of functions (shortcuts, single, and simple operator actions);
3 logical grouping of related information; and
4 access requirements for essential information and functions.

Consistency has been identified as the first most significant standardization design principle that increases usability. Using location and grouping for consistency provides for recognition as the second design principle. The third is frequency of use – sorting, grouping and locating of information according to frequency of use increases efficiency. This principle requires that navigators can access those tasks that they frequently use. It includes the application of hot keys, and single operator actions. The fourth principle is visibility of system status and integrity that includes visibility of "processing" information and the correct functioning of system sensors to illustrate degraded information. Projection to real world is the fifth with two elements: 1) using imaging or wording that is contextually related to the task, 2) geolocation of information providing a linkage, or correlation, between the user, electronic equipment and the real world relative to the ship. The sixth is resistance to erroneous operations including keeping navigation critical information on top of any interlaid information. And the last but not least, identified as seventh standardisation design principle, is navigator's assistance by user friendly help functions.

All of these assumptions should guarantee a very solid foundation for future navigation equipment design standards leading to easier operation and less operator's workload. Nevertheless, a critical analysis of current content of S-Mode guidelines' appendices reveals some potential issues that could actually lead to inconsistency with other IMO instruments and well established good practices of seafarers' education and navigation equipment operation.

3 POTENTIAL ISSUES

Appendices 2 to 5 of the S-Mode guidelines provide information on 2) navigation-related terminology and icons of functions including hot keys and shortcuts, 3) logical grouping of information, 4) list of functions that must be accessible by single or simple operator action, 5) default and user settings.

Potential issues identified in these appendices are:
1 Large number of new icons and abbreviations.
2 Problems with the interpretation of several default settings related to:
   – range and scale of data presentation,
   – stabilisation of data presentation,
   – look ahead function.

The large number of newly introduced icons and abbreviations in the S-Mode guidelines' appendix 2 seems to be inconsistent with the aim of the guidelines to locate and understand important information quickly. The numbers of recommended icons for hot keys are: 40 for general navigation functions, 42 for control of chart display functions, 4 for control of chart functionality, 2 for route plan and monitoring functions. The number of icons for shortcuts to groups of functions is 10. These numbers are doubled by the abbreviations corresponding to icons with few cases where icons are exactly equivalent to abbreviations. There are 7 standalone abbreviations for database functions, and 1 for look ahead function (icons are not applicable). Together, there are 204 icons and abbreviations introduced. Taking into consideration hot keys only, their number of 82 is close to 101 of traditional PC "qwerty" keyboard and it will surely imply at least several hours of familiarization training. As there are only vague suggestions to the order of hot keys presentation like: logical grouping, containing shortcut buttons under one setting menu rather than adding many icons to the desktop, and keeping the display area clear of clutter, one can assume that variations of hot keys positions across different manufacturers' keyboards or software menus would not be minimal. One should not be surprised as well if the group of general navigation hot keys are fixed with significant variation between navigation systems and equipment produced by different manufacturers (see Figure 1 showing typical INS / ECDIS keyboard). So, only after practicing and some experience gained, the user will locate the correct key quickly and independently of the system used.

The second identified issue of S-Mode guidelines are problems with the interpretation of several default settings defined in appendix 5. A set of default settings has been defined in order to return the equipment to a known default state after equipment failure or user command. Those settings are also intended to provide a basic and minimal mode of operation for the equipment that can be further built upon by the user.

Figure 1. Keyboards of typical contemporary INS

The first problematic default setting is default *range and scale of data presentation*. ECDIS setting of "Range / Scale" configured in response to "Default" selection has been fixed by the guidelines to 3Nm. Corresponding radar equipment setting of "Range" configured in response to "Default" selection has been fixed to 6Nm. Those settings have been adopted from Appendix 6 of IMO Performance Standards for INS [IMO, 2007] for "route monitoring task" and "collision avoidance task". As the adopted values are reasonable with appropriate display offset: at 3Nm the chart details significant for route monitoring should be clearly presented and at 6Nm with applied offset the time for anti-collision action should be sufficient (though it can be disputed for high speed crafts or generally vessels sailing over 20kt where the reaction time can shrink to less than 10min in case of reciprocal courses), still the confusion may arise to the range setting of ECDIS display. Some contemporary ECDIS systems recalculate user selectable scale to range and vice versa (Figure 2). Others use scale setting only.
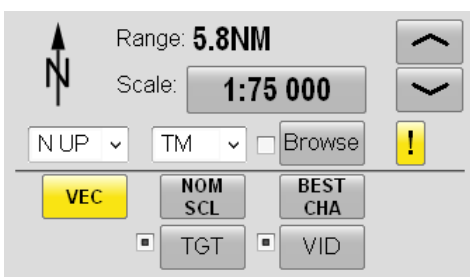

Figure 2. Example of ECDIS scale panel with range recalculated

IMO Resolution MSC.232(82) [IMO, 2006] specifies the effective size of the chart presentation for route monitoring in ECDIS as at least 270mm×270mm and 250mm×250mm or 250mm diameter for back-up system. Specifications for the ECDIS display screen are further set by IHO in requirements of S-52 [IHO, 2015] setting resolution as: minimum lines per mm (L) given by $L=864/s$, where s is the smaller dimension of the chart display area. (e.g. for the minimum chart area, s=270mm and the resolution L=3.20 lines per mm, giving a "picture unit" or pixel size of 0.312mm). The IMO ECDIS performance standards requirements

together with the display resolution requirements [IMO, 2006; IHO, 2015] usually result in the use of 19" or larger flat panels for ECDIS installations [Jonas, 2003], though smaller screens are also acceptable. Range to scale recalculation can be formulated in general as:

$$S_d = 1852000 \frac{R}{l_s} \qquad (1)$$

where:
S_d – scale denominator,
R – the mariner's selected viewing range in Nm,
l_s – length of the shorter side (usually vertical) of chart display area in mm:

$$l_s = \frac{25.4 d r_d}{\sqrt{r_n^2 + r_d^2}} \qquad (2)$$

where:
d – length of chart display diagonal in inches,
r_d – denominator of chart display ratio (where the ratio is defined as proportion of horizontal to vertical chart display length),
r_n – numerator of chart display ratio.

Because selecting a display scale in ECDIS usually means choosing from a list of scales fixed somewhat arbitrary by the producer (for example 1:500,000, 1:250,000, 1: 100,000, 1:75,000, 1:50,000, 1:25,000, 1:10,000, 1:5,000) thus, it can be expected that the recalculated range will not fit the 3Nm as default setting. In Table 1, in black, the resultant chart scales for typical off-the-shelf ECDIS monitors are shown according to (1). In red, the scale for a hypothetical display meeting minimum IMO standard of chart presentation (270mm×270mm) is shown.

Table 1. Chart scales corresponding to range of 3Nm

Chart display ratio r_n: r_d	Chart display diagonal d	Size of display l_s	Chart scale 1:S_d
5:4	17.1"	271mm	1:20,477
5:4	19"	302mm	1:18,429
5:4	21"	333mm	1:16,674
5:4	23"	365mm	1:15,224
4:3	18.0"	274mm	1:20,254
4:3	19"	290mm	1:19,188
4:3	21"	320mm	1:17,360
4:3	23"	350mm	1:15,851
16:10	20.1"	270mm	1:20,533
16:10	24"	323mm	1:17,197
16:10	32"	431mm	1:12,897
16:10	40"	539mm	1:10,318
16:9	22.0"	274mm	1:20,280
16:9	24"	299mm	1:18,590
16:9	32"	399mm	1:13,943
16:9	40"	498mm	1:11,154

Basing on Table 1 it is evident that mariner will either get different chart scales for the same range on different ECDIS screens or more commonly the scale of 1:25,000 as the closest smaller to the one equivalent to 3Nm range. It is assumed that ECDIS manufacturer designs system properly to find the smaller scale to the one recalculated and to load the dataset of the better larger scale chart if present. In few cases of

screens larger than 40" it will be also possible to display charts in scales of 1:10,000 or higher. In time the problem of data coverage definition for 3Nm range will probably lessen as the new IHO ENC Product Specification S-101 is introduced [IHO, 2018]. S-101 states clearly: "When the systems viewing scale is smaller than the value indicated by minimum display scale, features within the Data Coverage feature are not displayed, except where the SENC does not contain a dataset covering the area at a smaller scale, in which case the dataset will be displayed at all smaller scales. When the viewing scale is larger than the value indicated by maximum display scale, the overscale indication, in the form of an overscale factor and pattern covering the area that is overscale, must be shown. When own ship's position is covered by a dataset with a larger maximum display scale than the mariner's selected viewing scale (MSVS) an indication is required and should be shown on the same screen as the chart display". Anyway, the issue with range / scale setting will exist as long as the vagueness of related default settings: "Selected sea area: Around own ship with appropriate off-set" in ECDIS, and "Off Centre, with appropriate look ahead" is not interpreted unambiguously. One can even speculate that there are some fuzzy terms, like "appropriate" in S-Mode guidelines instead of standardized crisp ones.

The second somewhat problematic issue with default settings is *stabilisation of data presentation*. In the S-Mode guidelines the data presentation has been adopted as "ground" stabilised in ECDIS and "sea" stabilised in radar. While this is correct on grounds of Colregs (anti-collision regulations at sea are based on heading and speed through water, so sea stabilisation is appropriate for radar while ground stabilisation for route monitoring on chart) it will probably lead to some confusion of users of contemporary INS systems. In majority of them the same ground GNSS stabilisation is set in radar as in ECDIS by default which enables smooth transition of radar video and ARPA targets to chart display. New default settings will require extra caution while interpreting AIS and ARPA vectors in ECDIS and their potential fusion (see Figure 3).
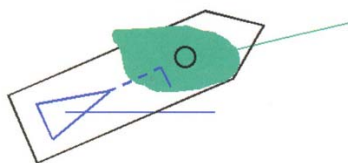

Figure 3. Ground stabilized AIS vector and sea stabilized ARPA vector in ECDIS

The third issue with the S-Mode default settings is *look-ahead setting*. Look-ahead related ECDIS setting configured in response to "Default" selection has been adopted as "Look-ahead time 6 min". Look ahead related radar setting configured in response to "Default" selection is quite different: "Off Centre, with appropriate look-ahead". Is it clear that radar setting concerns display offset while ECDIS setting concerns future prediction of ship's position? The same "look ahead" terminology can be misleading if it defines offset distance in one equipment and prediction time in another. On the other hand, in

contemporary ECDIS systems look-ahead terminology is not present except some definitions in user manuals. Instead other equivalent terms and functions are used. So the standard look-ahead term is very welcomed.
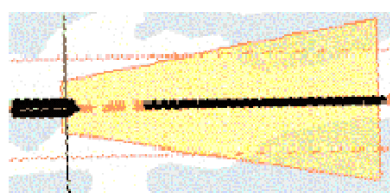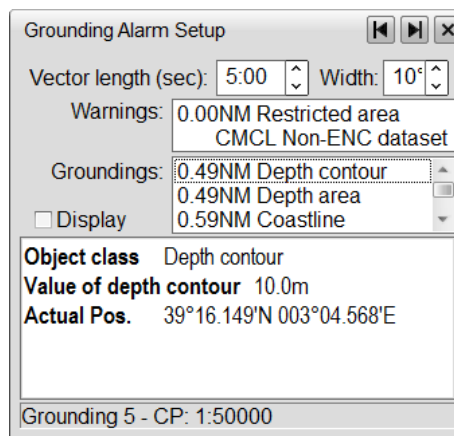

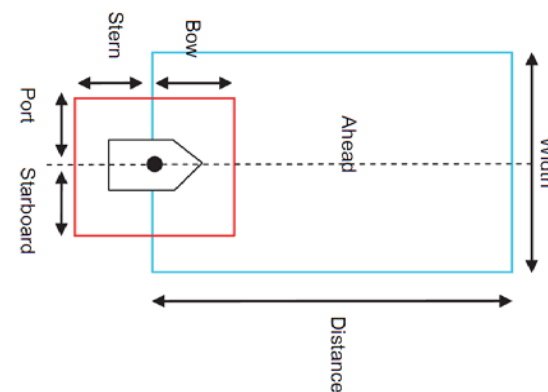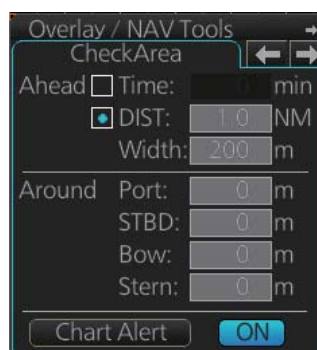Figure 4. Grounding alarm setup in example ECDIS

Figure 5. Check area setup in example ECDIS

In Figure 4 example of "Grounding Alarm Setup" dialog equivalent to "Look-ahead Setup" is shown. The *Vector length* and *Width* for the grounding alarm is specified in this dialog. So, the dialog contents are: look-ahead time specifying how far ahead (in seconds) grounding checking is to be performed, and

width specifying in degrees the widest part of the grounding check area, usually up to 30º.

In Figure 5 example of "Check Area Setup" dialog equivalent to "Look-ahead Setup" is shown.

Calculation of *own ship predicted movement area* is done using a *check area* in front of own ship position. The ahead time or distance and ahead width can be set (marked in blue in Figure 5). Additionally, the "Around": port, starboard, bow and stern check distance can be set (marked in red). The reference point is the conning position.
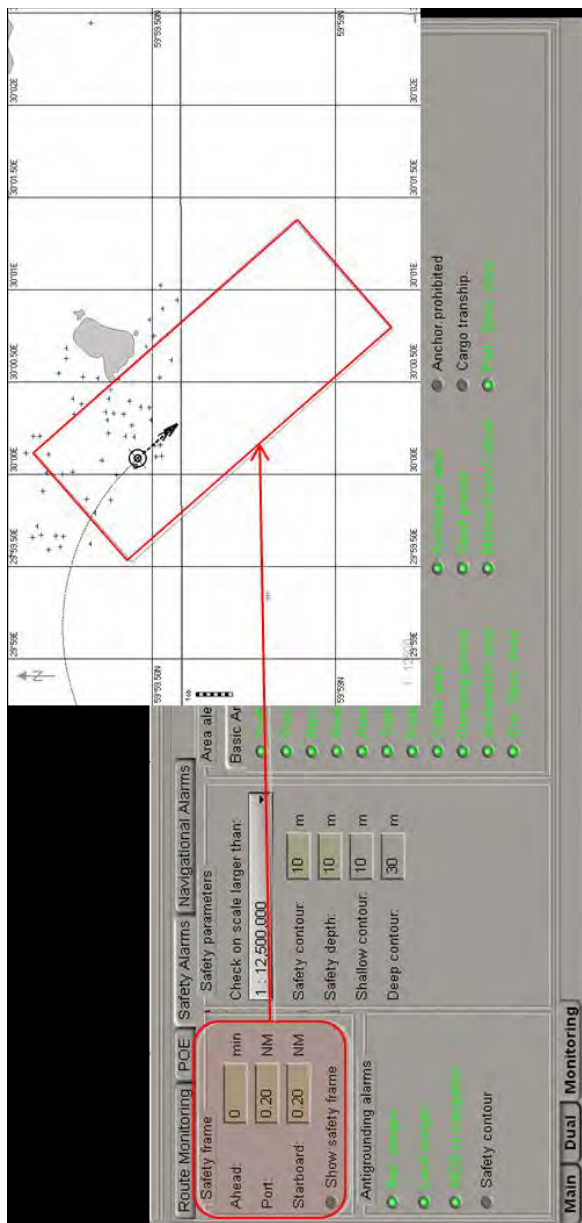

Figure 6. Safety frame setup in example ECDIS

In Figure 6 example of "Safety Frame Setup" dialog equivalent to "Look-ahead Setup" is shown. The Safety frame group is intended for setting the size of the frame, which will be used for the chart data analysis and for the generation of the anti-grounding alarms, area alerts and navigational alarms. Ahead is the window for the input of advance time for alarm or warning generation. The time value determines the length equal to the distance covered by the ship proceeding at the current SOG. Port is the window to set the width of the corridor to the left of the ship.

Starboard is the window to set the width of the corridor to the right of the ship.

One more important conclusion is evident after analysing Figure 4, Figure 5, and Figure 6. The S-Mode guidelines specify only one parameter of look-ahead function: time. However, look-ahead function implemented in ECDIS is multi-parameter. The user has to set not only prediction time but also width or port and starboard distance. Additionally in some systems a smaller "Around" area can be set and ahead distance can replace prediction time. IMO Guidelines for the presentation of navigational-related symbols, terms and abbreviations [IMO, 2019b] present look-ahead function as 2D area as well (Figure 7).
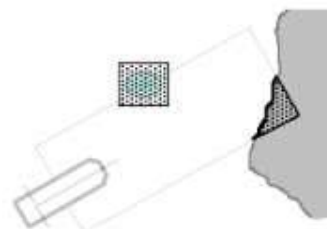

Figure 7. Look ahead alarm highlight [IMO, 2019b]

That means that at least the width parameter which in some systems is defined as arc and in others as length has not been standardized. So, significant variation between navigation systems and equipment produced by different manufacturers can be expected after activation of look-ahead time default setting.

Similar issue is valid for look-ahead offset. This function is expected to cause the system to move the own-ship symbol on the screen to the position that gives the maximum possible *look-ahead*. For example, if the vessel is sailing from west to east, resetting the centre should position the own-ship symbol close to the left edge of the display and cause the vessel's course vector to point through the centre of the display. Anyway, the offset distance for default range has not been stated specifically.

4 CONCLUSIONS

There is a number of IMO instruments and other international standards that deal with system design and information portrayal [IMO, 2006, 2007; IHO 2015]. The S-Mode guidelines have been developed not only on base of HCD but also on such standards. Such approach is generally assumed to bring positive effects, but in cases of uncritical adoption of source standards it can also bring negative ones. In case of S-Mode guidelines the discrepancy of several INS, ECDIS and radar equipment descendant functions is an example of such process.

If the S-Mode guidelines significantly affect navigation safety in positive sense remains a question that will be answered by simulation tests performed before implementation of modified equipment onboard vessels. Without conclusions from such tests [Zalewski, 2012] some guidance in the S-Mode guidelines can be dubious and actually inconsistent with well-established seafarer's practice. User

feedback testing, stressed as key factor, is recommended to confirm conformance with these guidelines, especially before implementation of systems designed in accordance to new Performance Standards for the Presentation of Navigation-related Information on Shipborne Navigational Displays [IMO, 2019a], coming in force in 2024.

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